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ENERGY REQUIRED TO DRY WOOD

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ABSTRACT

Ponderosa pine and Douglas-fir test specimens were dried by means of two drying schedules. The total electrical energy data, watt-hours required to dry the specimens to either 15 or 30 percent moisture content, were analyzed statistically. Models, based on all study data for each species, were also developed.

The wood drying process can be divided into three major stages: (1) warmup period; (2) the constant rate period; and (3) the falling rate period. In the warmup period, energy is required to heat the drying environment and the material; consequently, the rate of moisture loss from the wood surfaces is relatively slow. In the constant rate period, the energy requirement is fairly uniform as moisture moves through the wood (primarily by capillary action). Moisture is lost at a constant rate. The rate itself depends on the ability of the circulating air to remove water from the wood surfaces. In the falling rate period, the energy requirement increases considerably. Energy is required to rupture the bond between water and cellulose or lignin molecules as well as to diffuse moisture vapor to the surface. In this period, the rate of drying decreases with a decrease in the amount of moisture.

In most wood drying operations, the total energy used exceeds that required to dry wood at the optimum rate. Because energy consumed is one of the direct costs of drying wood, information concerning this factor is needed if the drying process is to be evaluated. The following study was made to evaluate the energy requirements of two different drying regimes--(1) in which the surface temperature was maintained at a relatively constant level; and (2) in which the oven temperature was held constant throughout the drying period. It was believed that less energy would be required by the surface temperature regime because of its more direct control over the drying process.

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PROCEDURE

Two ponderosa pine and two Douglas-fir boards were used in this study. The newly awn, select boards, 1 by 8 inches by 16 feet, were obtained at local Missoula sawmills. boards were cut into test specimens, 20 inches long. The specimens, identified as to board and position within board, were stored under water to prevent drying until needed.

Specimens were dried in accordance with one of two drying regimes. In the first regime, the oven was set at 138° C. (280° F.) and maintained at this level throughout the drying period. In the second regime, surface temperature of the specimen was held t 90° C. (194° F.) by decreasing the oven temperature until consecutive oven temperaure readings (taken 15 minutes apart) were the same. At this time, the surface temperture of the test specimen was slightly less than the oven temperature. The oven was hen returned to its original setting of 138° C. and maintained at this setting for the emainder of the drying period. For all specimens, the oven was started after the specmen had been positioned inside. The initial temperature setting was 138° C.

During the drying period, specimen weight, surface temperature, and oven temperaure were recorded at 15-minute intervals. In addition, chart records were obtained of the electrical consumption (watt-hours) and the surface temperature. At the completion of the drying period, the specimen was placed in a second oven and dried to a constant weight. This constant (ovendry) weight was used to calculate the specimen's specific gravity (green volume) and the initial and intermediate percent moisture contents.

Four specimens, selected at random from each board, were dried in accordance with each of the two drying regimes; thus eight ponderosa pine and eight Douglas-fir specimens were dried at constant oven temperature and the same number of each species were dried at constant surface temperature.

RESULTS AND DISCUSSION

Data obtained from the test specimens are summarized in table 1. The mean specific gravity of ponderosa pine board 1 specimens was 0.441 and the range 0.028; the average initial percent moisure content was 149 and the range 23 percent. For ponderosa pine board 2 specimens, the average specific gravity was 0.503 and the range 0.091; the average initial moisture content percent was 115 and the range 41 percent. For the Douglas-fir test specimens obtained from board 1, the average specific gravity was 0.408 and the range 0.059; the average initial percent moisture content of these specimens was 88 and the range 42 percent. For board 2, the average specific gravity was 0.403 and the range 0.077; the average initial percent moisture content was 109 and the range 74 percent.

Contrary to expectation, ponderosa pine boards had a higher specific gravity than Douglas-fir boards. However, the average initial percent moisture content was usually greater for ponderosa pine specimens than for the Douglas-fir specimens, as was expected.

Other data shown in the table are the average times, in minutes, needed to dry the specimens to average moisture contents of 30 and 15 percent, and the average watt-hours required to attain these moisture contents. As would be expected, the average times and the average watt-hours required to dry to 15 percent moisture content were greater than were needed to dry to 30 percent moisture content. A comparison of the drying regimes shows that the constant surface temperature schedule usually required longer average times and greater average watt-hours.

Table 1.--*Summary of the data for all test specimens*[1]

Board no.	Drying schedule[2]	Average specific gravity	Average initial moisture content	Average time to dry to 30% MC	Average watt-hours to dry to 30% MC	Average time to dry to 15% MC	Average watt-hours to dry to 15% MC
			Percent	*Minutes*		*Minutes*	
			PONDEROSA PINE				
1	COT	0.442	146	172	16,555	225	20,345
	CST	.439	153	188	15,771	266	19,805
2	COT	.507	109	172	16,699	248	21,829
	CST	.499	122	229	17,379	311	22,615
			DOUGLAS-FIR				
1	COT	.409	79	120	12,165	199	17,061
	CST	.406	98	254	14,822	270	19,561
2	COT	.395	105	169	15,899	244	21,516
	CST	.411	113	225	16,880	308	22,771

[1] Each value in the table is the average of four test specimens.

[2] The drying schedules used were constant dry bulb or oven temperature (COT) and constant surface temperature (CST).

The total watt-hours of electrical energy required to dry the individual test specimens to moisture contents of 30 and 15 percent was subjected to analysis of variance. None of the controlled study variables were significant.

Since no differences were detected between drying regimes, a model was developed using all the data for each species to show the relationship between watt-hours of energy required to dry to 15 percent moisture content, initial percent moisture content, and specific gravity. The Douglas-fir model (fig. 1) had the following equation:

Watt-hours to 15 percent moisture content

$$= \left[A - \left\{ \frac{A - 4}{(145)^N} \right\} (160 - IM)^N \right] 1011.854$$

where:

$A = 59.091\ (SG) + 1.736$

$N = 4.0909\ (SG)$

IM = Initial percent moisture content

SG = Specific gravity

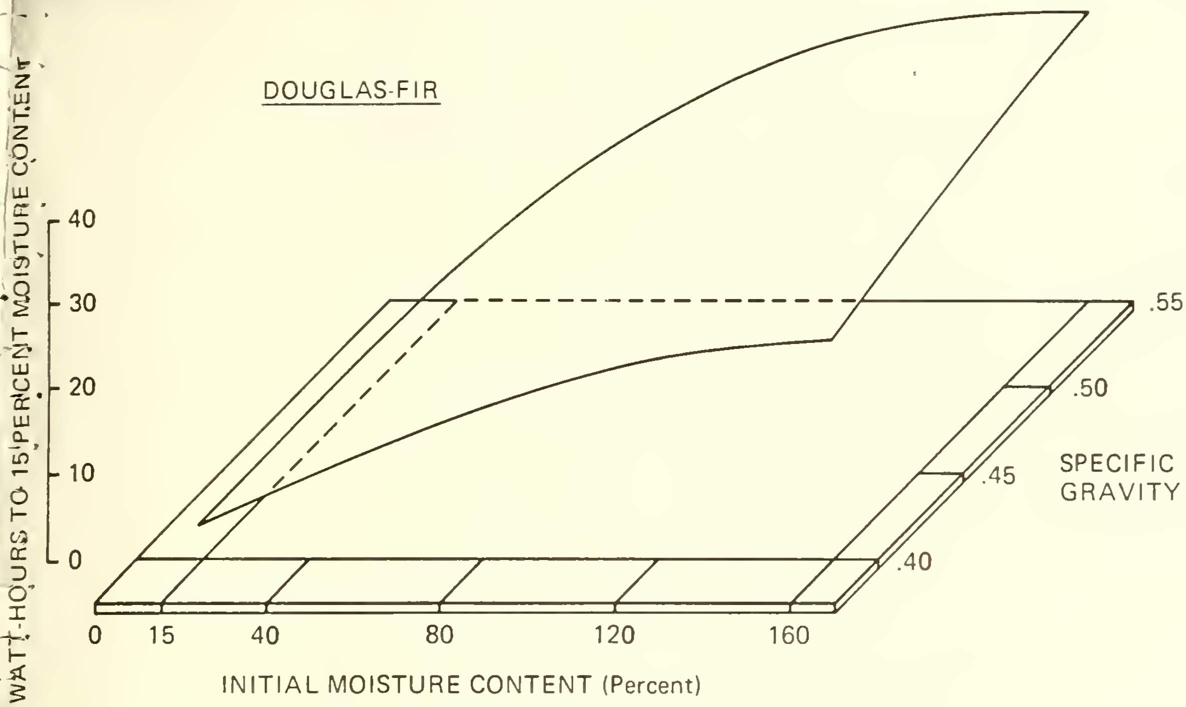

Figure 1.--Douglas-fir model showing relationship between watt-hours required to dry to 15 percent moisture content, initial percent moisture content, and specific gravity; $R^2 = 0.80$; standard error of estimate 1,200; mean watt-hours was equal to 20,227, based on 16 test specimens.

The model limits were: specific gravity 0.35-0.50 and initial percent moisture content, 60-160. The equation, based on 16 specimens, has an R^2 of 0.80 and a standard error of estimate of 1,200 watt-hours.

The model shows that the specific gravity and initial percent moisture content variables were positive as expected, and an increase in either value increased the watt-hour requirement.

The ponderosa pine model (fig. 2) has the following equation:

Watt-hours to 15 percent moisture content

$$= \left[A - \left\{ \frac{A - 4}{(145)^N} \right\} (160 - IM)^N \right] 977.062$$

Where:

A = 100 (SG) - 22.7

N = 3.0645 (SG) - 0.291

IM = Initial percent moisture content

SG = Specific gravity

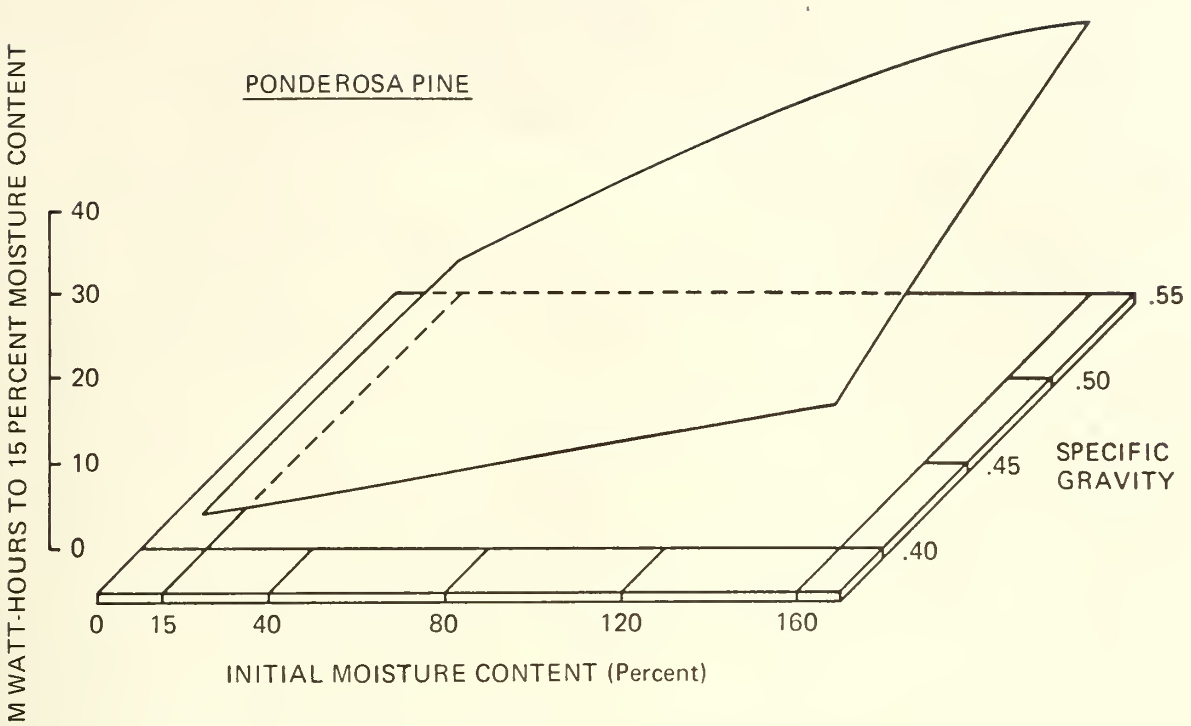

Figure 2.--Ponderosa pine model showing relationship between watt-hours to dry to 15 percent moisture content, initial percent moisture content, and specific gravity; $R^2 = 0.20$; standard error of estimate 2,100; mean watt-hours was equal to 21,148, based on 15 specimens.

The data limits for the model were: specific gravity, 0.40-0.55, and initial moisture content, 90-160 percent. The equation, based on 15 specimens, has an R^2 of 0.20 and a standard error of estimate of 2,100.

One reason for the weakness of the ponderosa pine model is the somewhat narrower range in the initial moisture content of the test specimens. The average range was 32 percent; that for the Douglas-fir was 58 percent.

CONCLUSIONS

Results of this study indicated no significant difference between constant surface temperature and constant oven temperature regimes in the total electrical energy (watt-hours) required to dry wood specimens to a given moisture content. This is contrary to expectation in that the test specimens were subjected to different drying regimes and were of different species, specific gravity, and initial percent moisture content.

Models, based on the study data, show that the effects of specific gravity and initial percent moisture content were positive and interactive; so an increase in either variable increased the watt-hour requirement.

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